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WATER LEVEL MEASUREMENT FROM A FLOATING ICE COVER

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CANADA

ABSTRACT

Water level data suitable for tidal analysis may be obtained by the use of mechanical water level recorders mounted on freely floating ice covers providing that auxiliary measurements are made to correct for ice loading from snow accumulation and for the increase in freeboard due to ice growth. This paper describes the selection of suitable sites, techniques for installing recorders and auxiliary measurements.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

In an analysis of the forces acting on the ice cover of Robeson Channel and Fury and Hecla Strait N.W.T., water level recording was required from stations along the shores of these channels. Budgetary limitations dictated the use of mechanical float-type water level recorders. By employing simple techniques and calibration procedures, data suitable for tidal analysis were obtained.

FIELD EXPERIENCE

From April to June 1975, five tide recorders were operated along the Ellesmere Island and Greenland coasts of Robeson Channel. In April and May 1976 six recorders were installed on the coasts of Melville Peninsula, Baffin Island and Crown Prince Fredrick Island in the Fury and Hecla Strait area. These units were installed and serviced by a De Havilland DHC-2 Beaver aircraft on ski-wheels; this aircraft was shared with parties carrying out other oceanographic studies. The following paper is based on this experience, plus low temperature trials on the Ottawa River in 1974 and at two locations in Fury and Hecla Strait in the spring of 1975.

Because of its rugged enclosure and simple standpipe mounting the Ott type R-16 water level recorder, (Figure 1) was modified to record the distance from a floating ice cover to an anchor located on the bottom (Figure 2). All parts and associated equipment for installation and recovery will fit in a De Havilland DHC-2 Beaver aircraft (Figure 3). The following procedures and modifications would apply to any similar mechanical recording system.

SITE SELECTION

While the general location for the water level station will be decided when a survey is planned, the actual site will depend on local factors. One of the prime requirements in choosing the site for a tide recorder on fast-ice is to insure that the recording chart changes and calibration checks will be easy to perform as this will have to be done on a routine basis. Snow and ice conditions as well as prevailing winds will have to be considered, particularly if fixed wing aircraft are to be used to reach the stations.

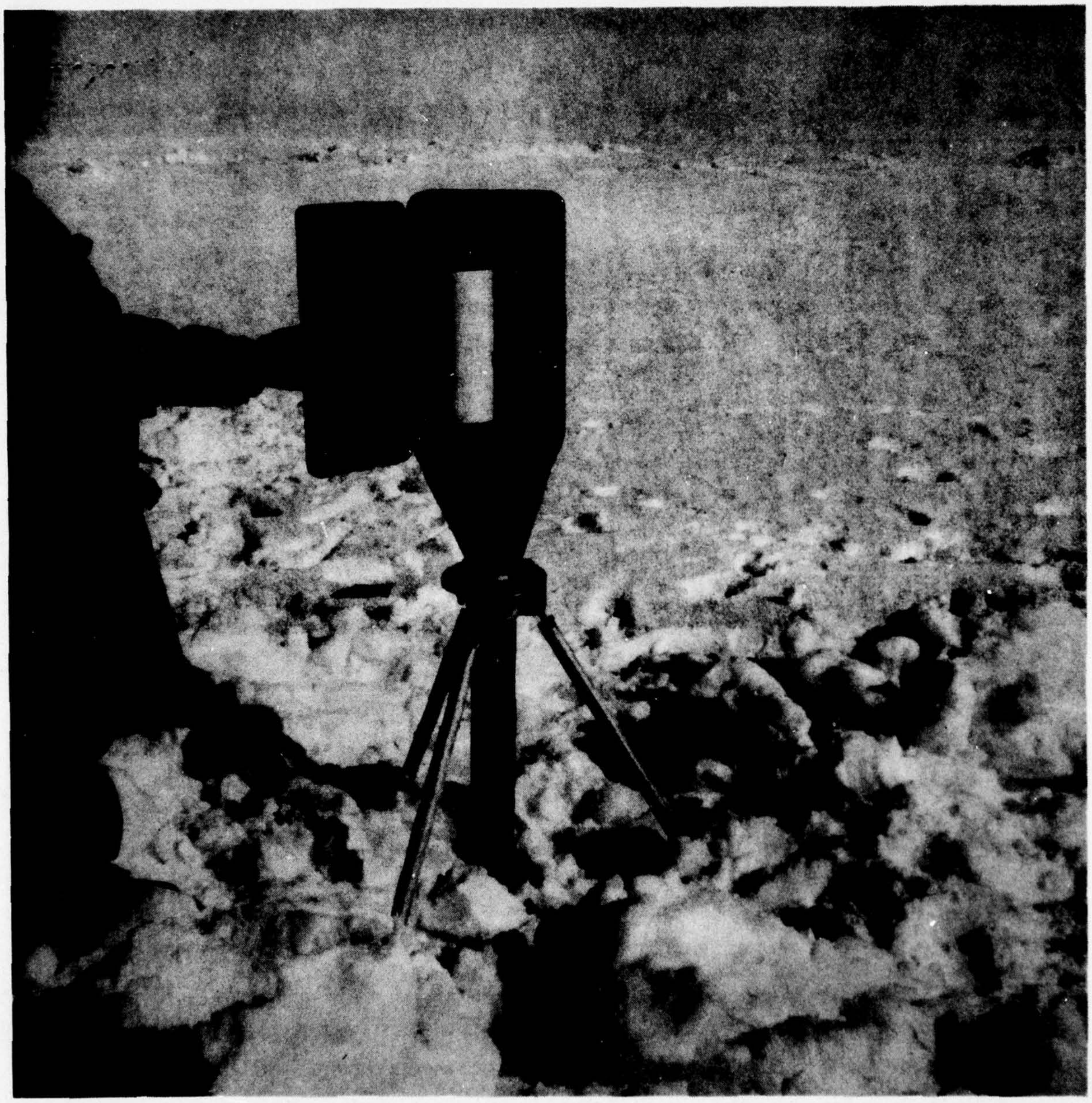

Figure 1. OTT Type R-16 Water Level Recorder

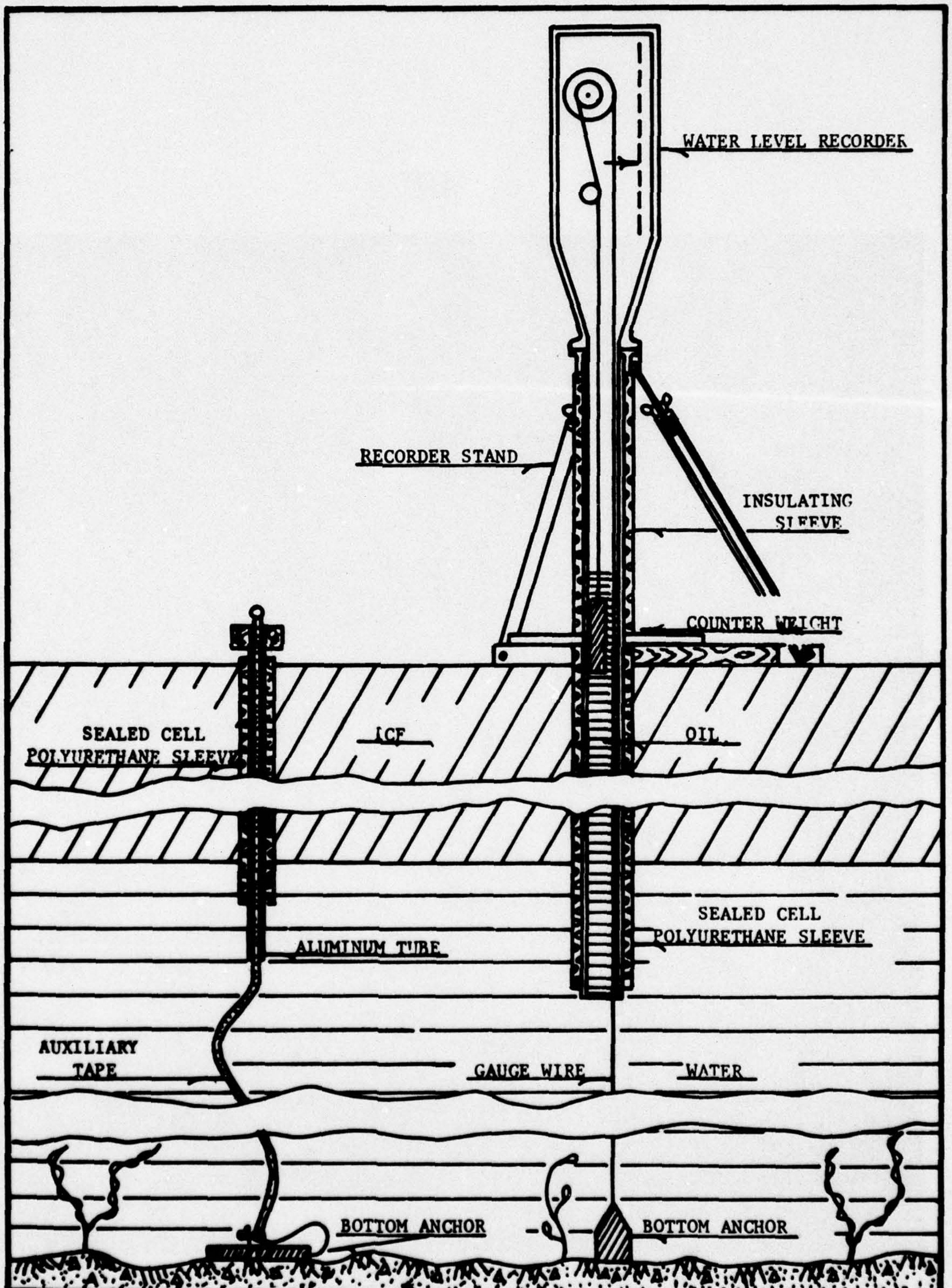

Figure 2. Installation of Water Level Recorder

Figure 3. De Havilland DHC-2 "Beaver" at a Water Level Recorder Site

A flat area of first-year fast-ice free of any ridges or old ice right up to the tide crack, is required. This condition will also help meet other requirements of the site. On a clean flat sheet of fast-ice one is not likely to encounter heavy drifts or excessive snow accumulation. Snow loading of the ice is one of the problems associated with this method of measuring water level but the problem can be minimized by choosing an exposed stretch of ice and this will be discussed further below.

Prevailing winds are another consideration for the STOL airstrip used in maintaining the gauge. Information on prevailing winds is available from published climatic data which can be modified by local residents knowledge or by snowdrift orientation. Four-metre aluminum tubes with flags secured to them should be frozen into holes drilled into the ice to mark out the airstrip and to indicate wind direction for subsequent landings.

The next step is to pick the actual site for the recorder. The gauge must be located beyond the tide crack farthest from shore as it is the vertical movement of the recorder itself relative to a fixed bottom mounted anchor weight which produces the level change recorded. Along a steep shore only a few relatively prominent cracks are usually found, whereas in an area having a gently shelving bottom there are likely to be many cracks some of which will be small and obscure. The installation should be a fair distance seaward of the last tide crack to insure that the vertical movement of the ice is not influenced by hinging. Gently shelving coasts appear to afford more suitable ice conditions than do steep ones, although this also will depend on the wind and ice conditions at the time of freeze-up.

The type of bottom is of some importance as well. Once the anchor weight is set it is desirable that it should not move. A relatively smooth firm bottom is desirable as in a mud bottom the weight may settle or on a rocky bottom the weight could drop if it is in an unstable orientation. A cone-shaped weight is best as it has a broad base for stability and a pointed top to facilitate recovery through the standpipe.

If heavy old floes are frozen into the first year ice, it is important to avoid setting the recorder nearby, as the old floe may ground at low water of spring tides and influence the vertical movement of the surrounding ice.

Another consideration is the depth of water below the recorder. It has been found that only three metres of water below the bottom of the ice at

low tide on a gently sloping shore and seven metres on a steep shore are required. This should prevent the grounding of nearby ice at spring tides.

A final consideration in choosing a site is that of finding a suitable rock outcrop on the shore on which to establish a benchmark from which future hydrographic surveys can be referenced. The method described in the Tide Manuel of the Hydrographic Service for establishing a benchmark on permafrost cannot be used, since it is impossible to excavate a hole of adequate depth in spring and a rock outcrop is necessary. Small rocks frozen into the soil may be used as temporary benchmarks (minimum three per station) until the melt begins. Thereafter, with less snow cover, a suitable outcrop in the vicinity may be found. A metal tablet cemented into a hole drilled in the rock outcrop, or an expanding lead anchor may be used (Figure 4) to indicate the benchmark. The hole is usually drilled with a hammer and star drill (Figure 5), and a short length of rubber tube and protective goggles are required for blowing the rock dust from the hole while drilling. A written description, sketch and photographs of the benchmark are necessary to assist others in relocating the mark for future surveys.

INSTALLATION PROCEDURE

Having chosen the site, a 15-centimetre (or larger) hole is drilled through the ice. A PVC standpipe is set into the stand base and a foam, sealed cell polyurethane insulation and release tube is slipped over the outside. The bottom of the standpipe is fitted with a temporary seal, a sheet of heavy gauge plastic lashed in place with sail twine, which prevents water, ice chips and slush from entering the pipe prior to filling it with oil. The standpipe is aligned with the hole and the top end raised about one metre. It is then partially filled with kerosene, furnace oil, diesel oil or preferably JP-4 turbo fuel (because of its anti-icing additives) raised to a vertical position, lowered into the hole and topped up with oil.

A bottom anchor weight, preceded by a "plastic cutter" in the form of an inverted crown cut from a soft drink tin, is now gently lowered into the standpipe until the crown cuts through the plastic seal and falls away. The oil level in the standpipe should fall slightly as equilibrium is established, and this level relative to the top of the standpipe should be logged. The wire attached to the anchor weight is cut three metres longer than the anticipated wire length required at high water spring tides, then passed up through

FIGURE 4. Expanding Anchor Mounted Benchmark

Figure 5. Drilling Benchmark Hole

the base of the recorder. The unit is bolted to the stand with neoprene flat washers used to protect the corrosion resistant paint of the recorder. Snow may now be heaped about the base and standpipe for additional insulation (Figure 3).

If the recorder is to be used with an unmodified pulley, the most suitable one for the tide range to be expected is selected, the wire passed over it and the counterweight attached and lowered into the standpipe.

When using the modified pulley in the form of a 2:1 differential drum, the wire from the bottom anchor weight is secured through the hole near the rim at the rear of the larger drum and the slack wire evenly wound up in a single layer. The threading of the wire is shown in (Figure 6). The counterweight is similarly attached to the smaller drum with the length of the wire slightly greater than half the greatest tide range expected. Then the counterweight is attached and lowered into the standpipe. It is desirable that the counterweight remain inside the standpipe at the lowest water level expected. Knowing the state of the tide and the approximate range, this length can be adjusted at the time of installation. Without this information, a guess can be made and any correction required should be evident after a few days record is obtained.

The clockwork drive, drum, chart paper, pen and inkwell are installed following the manufacturers instructions. The clockwork drive should be kept in its sealed plastic container with active dessicant until installation and the unprotected clock should not be brought into a warm room or warm moist atmosphere. <u>All cold weather clockwork failures are due to ice crystals forming in the escapement lubrication from absorbed moisture</u>. The synthetic oil used for the lubrication of the clockwork drive is good to $-57^{\circ}C$ ($-70^{\circ}F$).

As most recorder inks consist of a dye, thinner and stabilizing additives, selective freezing out of one or more of these components may cause the pen to clog or the ink to run into the paper and spread from reduced surface tension. Equal parts of red and green "Esterline Angus" ink diluted with two parts of methyl alcohol is good to $-30^{\circ}C$, other inks such as "Belfort" #60 will work to $-60^{\circ}C$ if the rate of pen travel is low. When the pen and well are removed from the recorder they should be stored in a small vial of methyl alcohol to prevent the ink from drying out and plugging the syphon tube.

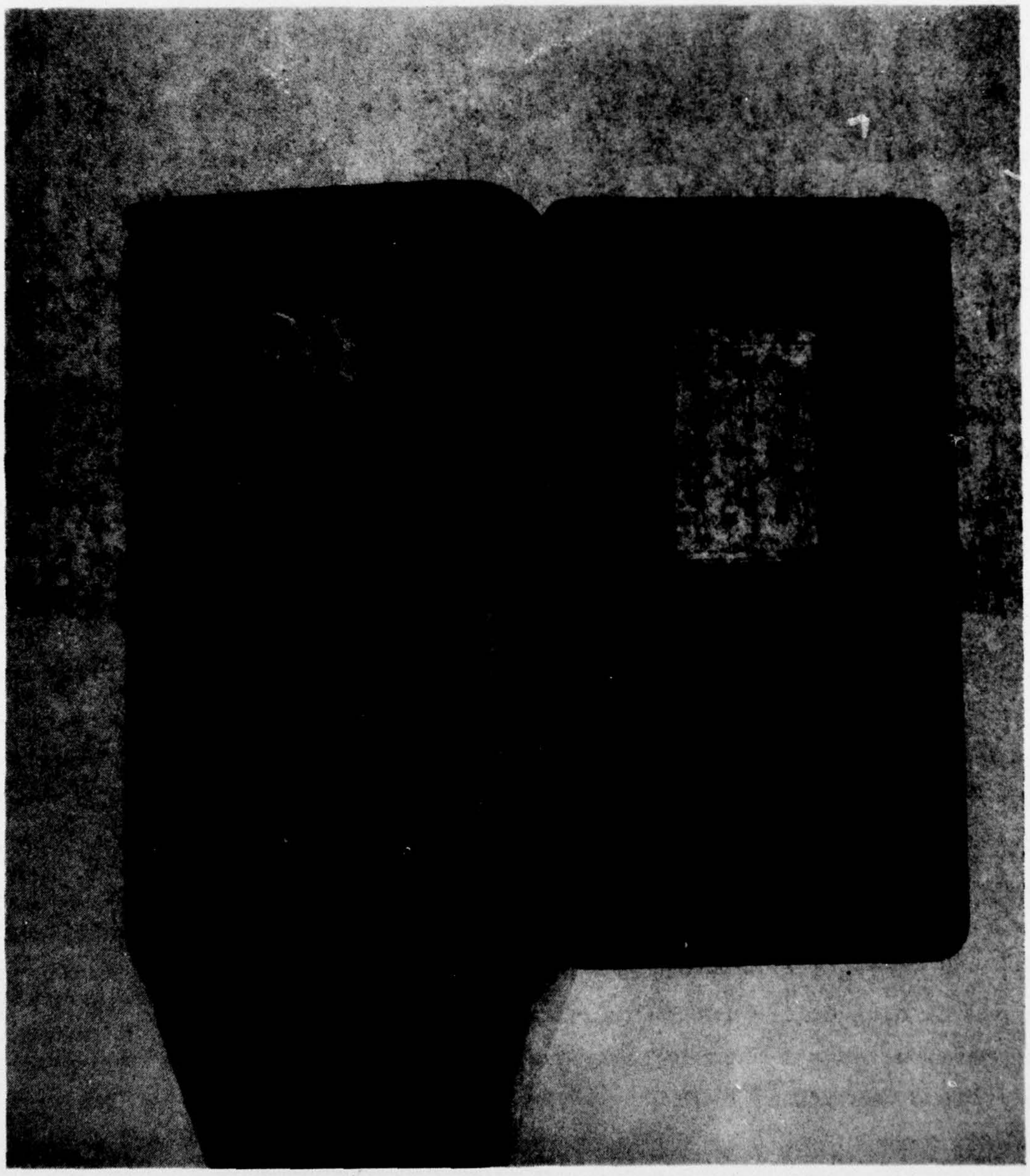

FIGURE 6. Wire Threading of the OTT Water Level Recorder

Isopropyl alcohol should not be used as it reduces the surface tension and results in excessive ink spread.

The small phosphor bronze spring mounted at the lower end of the chart drum is engaged in the mounting block and the drum backed against it one-half turn to provide an anti-backlash load against the clockwork drive.

A separate auxiliary measuring tape is installed at the location on the same ice structure that supports the water level recorder (Figures 2 and 7). This consists of a cloth metric tape attached to an anchor weight at the bottom ascending to the surface where it passes through a 2.5-centimetre aluminum tube encased in a polyurethane "release tube" frozen into the ice. The aluminum tube is readily broken free from the soft release tube and with-drawn so that the water level may be measured and logged. Backing the recorder drum at this instant against its anti-backlash spring will indicate on the chart the time of this leveling. The tape and aluminum tube are replaced in the "release tube" making sure that sufficient tape is free in the water below the ice to allow for the maximum tide range

OBSERVATION PROCEDURE

Once the water level recorder has been properly installed, it should operate for a full seven-day recording period without attention. However, as there are a number of minor difficulties which may occur, more frequent checks are desirable. When these checks are made, the observations required are:

1. time
2. chart time
3. chart reading
4. drum index reading
5. auxiliary water level tape measurement
6. snow depth
7. ice thickness
8. ice freeboard

In addition to the above observations; wind, weather and general snow and ice conditions are recorded, any necessary adjustments made, the clock wound and pen reservoir filled if necessary. When a new chart is installed the auxiliary tape measurement should be repeated, as the final drive to the pen mechanism is a friction drive and the pen may be inadvertently displaced when the chart change is made. The ice thickness can be determined by

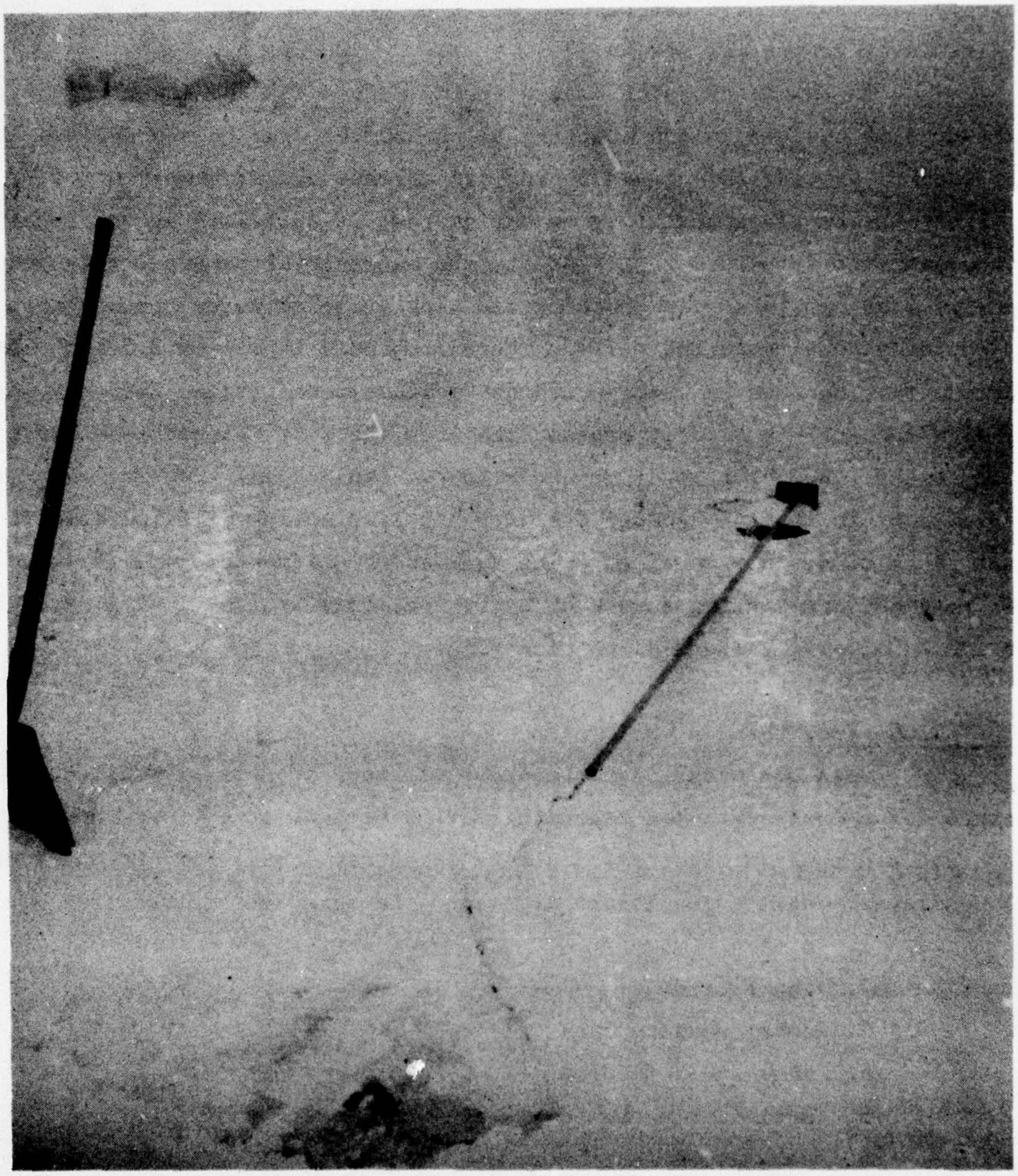

Figure 7. Auxiliary Measuring Tape for Recording the Water Level.

first drilling with a 2.5 or 3.8-centimetre Sipre hand auger and then using a measuring tape equipped with a toggle and trip line to measure ice thickness and freeboard. Note that there is no satisfactory way of determining freeboard when a hot-wire ice thickness gauge is employed. Considerable work can be avoided by re-drilling the same hole at subsequent visits. Snow depth is difficult to measure accurately and can best be obtained by taking the median of an odd number of depths around the water level recorder.

SOURCES OF ERROR

The greatest source of error in measuring tide with this method is that of snow loading which depresses the ice. The change in freeboard gives a direct measurement of this loading error and can be applied to the record, but again it is best to minimize the problem by choosing an exposed wind swept location on level ice where snow is unlikely to accumulate. A significant change in freeboard without any snow accumulation is an indication that the recorder has been set up on ice the vertical movement of which is being affected by grounding. The only remedy then is to relocate the recorder. A third reason for freeboard change is ice growth due to freezing. This correction will be small, typically 1 centimetre per month furing April and May when the ice has reached its maximum thickness.

The formation of ice in the standpipe should not be a problem after the end of March, if some should form however, it may be possible to knock it out by carefully lowering the spare counterweight on a line. The addition of a small amount of methyl alcohol mixed with fuel oil (e.g.: 500 ml of alcohol vigorously agitated with 500 ml fuel oil) to form a suspension of fine droplets slowly poured into the pipe at each visit, should eliminate ice formation.

If the insulating release tube does not extend to the bottom of the standpipe convection in the oil will cause ice to form on the outside of the projecting PVC tube, (Figure 8), and this ice may bridge over the bottom and block the tube.

LEVELLING

Levelling procedures for hydrographic work are fully described in the Canadian Hydrographic Tidal Manual. However, a few notes relating specifically to this method of tide measurement can be added. As the level must

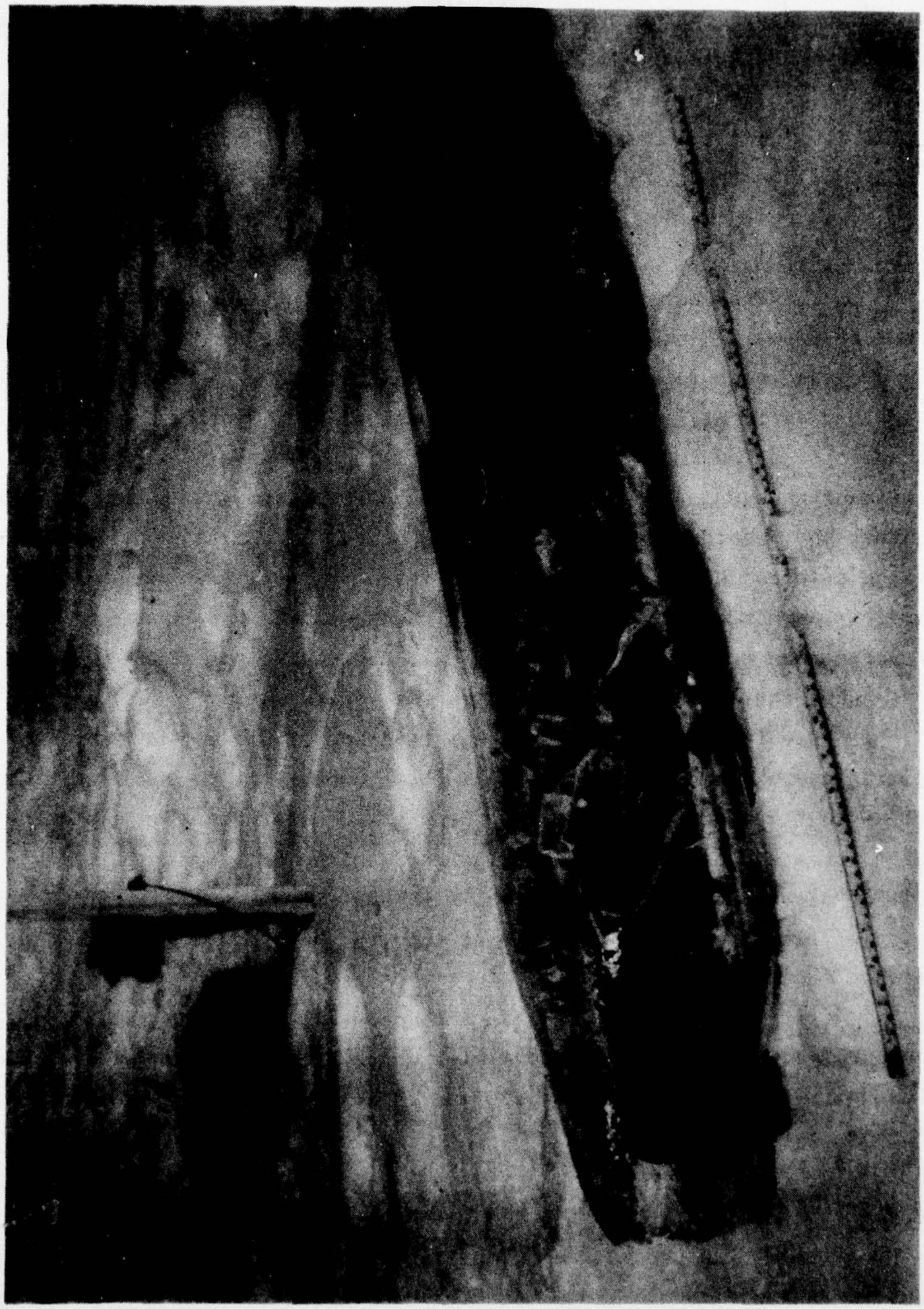

Figure 8. Ice Accumulation on an Uninsulated Standpipe

be set up on the ice foot or on shore, an exceptionally long foresight may be required, particularly on a gently sloping coast since the rod must be set up right next to the water level recorder. Careful and repeated observations in fine weather will reduce errors to a minimum. High ice ridges along the shore may pose another problem for levelling. This aspect must be considered when the site for the water level recorder is chosen.

The elevation difference required is from the water surface to the benchmark. In practice, levelling to the ice surface and adding the free-board measurement has been found the most practical way of obtaining this value. At the instant the rod is read, the recorder drum should be backed against its anti-backlash spring to mark the chart and then the auxiliary tape measurement made.

RECOVERY PROCEDURE

The removal of a water level recorder from a fast-ice installation can be carried out rapidly and all equipment can be recovered for further use leaving the location as it was before the installation.

After making the final comparison notes and ice measurements, the chart is removed and the recovery begins. The chart drum is withdrawn and the pen assembly removed for cleaning and storage in methyl acohol. The recorder housing is unbolted, removed from the stand and packed, with the chart drum separate, in the shipping case. A rope strop should be placed around the unit so that it may later be readily removed from the foam packing. The clock drive may be left mounted in the recorder housing. The anchor weight may now be broken free from the bottom and pulled to the surface. The liquid in the stand-pipe can be pumped out to prevent pollution and saved for re-use. The stand is disassembled and packed. At this time the standpipe can be twisted free from the release tube and withdrawn, and the release tube itself pulled from the hole. The auxiliary tape is recovered by simply pulling up the aluminum tube breaking the weight free from the bottom and pulling until the weight arrives at the bottom of the ice. A sharp tug will break the sail twine at the centre of the weight and it will fall to a vertical position and can then be withdrawn from the hole. Pulling out the release tube completes the recovery of the station equipment.

THE RECORD

The chart should be corrected for height and time errors and scaled manually in the field. A sample chart in shown in Figure 9. The data are recorded on the Hydrographic Services Tides and Water Level Form entitled "Tabulated Hourly Heights" (Form T.L.W. 501). The advantage of scaling the record in this manner is that the data are in a useful form immediately upon return from the field. Alternatively, the chart may be scaled with a chart reader which can be programmed to apply height and time corrections and list or digitize the hourly heights on paper or magnetic tape. This type of equipment is not normally available in the field and the data will not be available until months after the field work has been completed.

ADDITIONAL READING:

1. Tide-Gauge Installation on Shore-Ice, Employing (Auxiliary) Water Level Gauge. N.P. Irecki. Problemy Arktiki, 1959, 6, 117-119.

2. Hydrographic Tidal Manual. G. Dohler. Canadian Hydrographic Service, 1965.

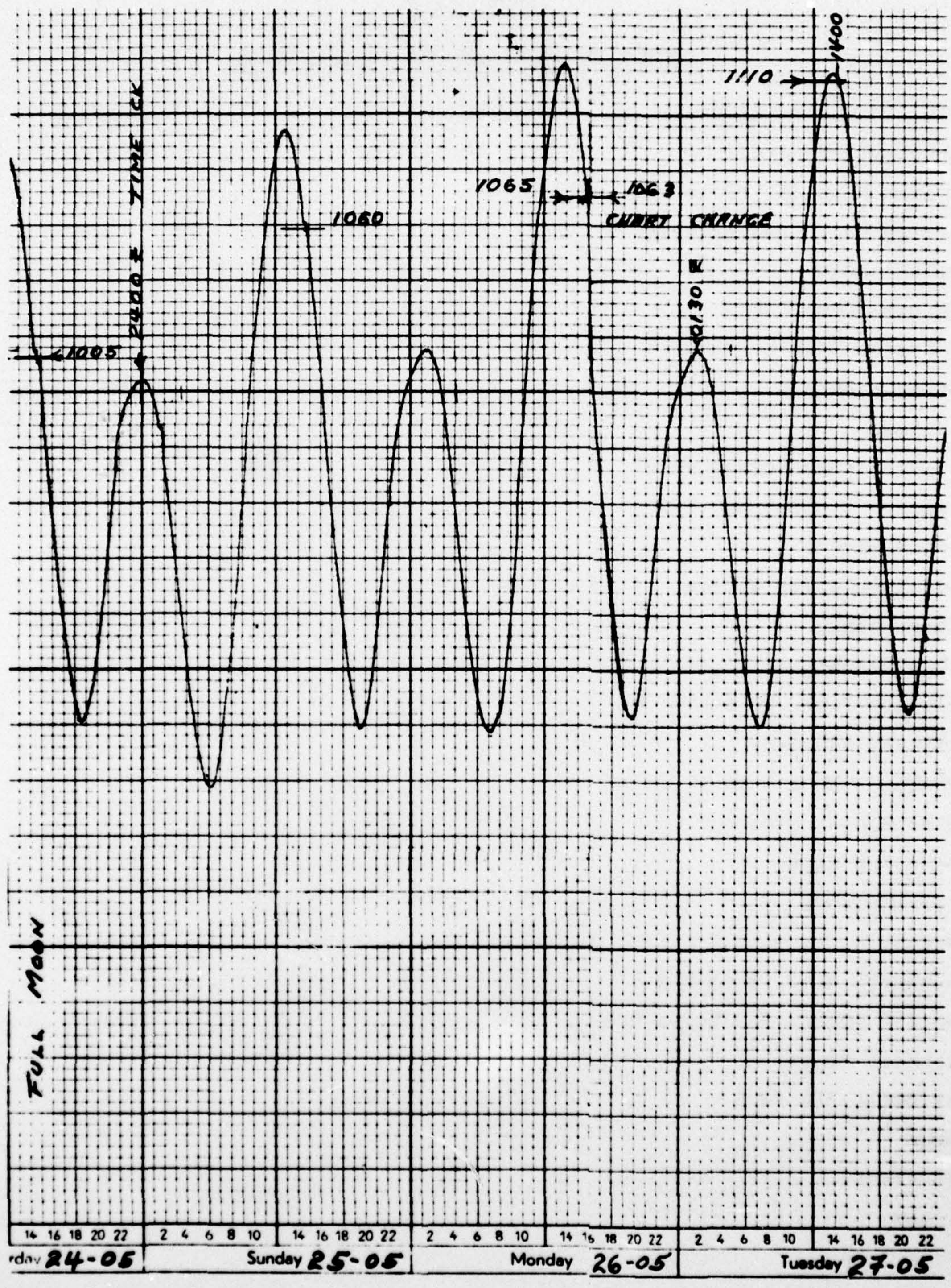

Figure 9. Sample Chart Record

APPENDIX A

EQUIPMENT REQUIRED FOR INSTALLATION

ITEM	QUANTITY
Water Level Recorder	1
Aluminum Mounting Plate	1
Mounting Bolts and Washers	5
Aluminum Legs	3
Aluminum Pins	3
S/S Cotter Pins	6
Wood Spreaders	3
Wood Base	1
Flat-Head Wood Screws #8x2"	15
Standpipe 3" IDx4 m. PVC	1
Release Sleeve	1
Upper Insulating Sleeve	1
Counterweight	1
Anchor Weight	1
Auxiliary Tape, 30 m	1
Auxiliary Anchor	1
Aluminum Tube 2.5 cm x 2 m	1
Rubber Bungs, Slotted	2
Wood Upper Stop	1
Release Sleeve	1
Shovel	1
Ice Auger, Min. 15 cm x 3 m	1
Hand Ice Auger, Thickness Kit	1
Benchmark Plugs	3
Star Drill 3/4 inch	1
Hammer	1
Screwdriver	1
Goggles	1
Rubber Tube	1
Level, Surveyors	1
Rod, Surveyors	1

ITEM	QUANTITY
Wrench, 3/4 inch	1
Chart Paper	1/week
Ink	-
Kerosene, Stove Oil, Diesel or JP-4	5 Gals.
Methyl Alcohol	1 Gal.
Levelling Record Sheets	10
Tabulated Hourly Height Sheets	1/month
Cut-off Pop Can	1
Plastic Sheet	20x20 cm
Sail Twine	-